Fermilab

Particle Physics Division

Mechanical Department Engineering Note

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Project: DECAM

Project Internal Reference: LN2 Testing at Lab A

Title: Trapped Volume Relief Valve Calculations, DECam LN2 Test LabA

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Key Words:

Abstract/Summary:

Trapped volume relief valves are sized for the DECam LN2 closed loop cooling system used for the Lab A Test. The required capacity of PRV-6202 is also calculated.

Applicable Codes:

ASME DIVISION I SECTION VIII,

CGA S-1.3 Pressure Relief Design Standards, Part 3 Stationary Storage Containers for Compressed Gasses

Introduction:

Trapped volume relief valves are sized for the DECam LN2 closed loop cooling system used for the Lab A Test. Trapped volume relief valves are located in any section of piping that can be isolated from the rest of the piping system. The largest isolated section of piping is the triple jacketed hose (Part #D010TVJAVCR-720). Two conditions are used to size the relief valve, loss of vacuum and exposure to fire.

The required capacity of PRV-6202 is also calculated.

SV-6311, 6306, 6303, 6408,6200

Trapped volume relief valve

CALCULATIONS

Finding required trapped volume relief capacity using CGA section 5.2.2, pressure relief device flow capacity for loss of vacuum

$$Q_a = \frac{0.383(328-T)}{(922-T)} F \times G_i \times U \times A$$

$$G_i = \frac{73.4(1660-T)}{C \times L} \frac{V_g - V_l}{V_g} \sqrt{\frac{ZT}{M}}$$

Where,

Qa = flow capacity of the relief device cubic meters per hr

F= 1 , correction factor

k=Cp/Cv = 0.538 BTU/Lb.R / 0.256 BTU/Lb.R = 2.1

C = 406 using Table 4 and constant k

L = 69.5 BTU/lb Latent heat at 180 Rankine

Vg =1/ 0.22 lb/ft^3 = 4.5ft^3/lb

Vl = 1/43.1 lb.ft^3 = 0.23 ft^3/lb

Z = 1 Compressibility factor.

T = 100K = 180 Rankine

M = 28 Molecular weight for nitrogen g/mole

U= k/l = overall heat transfer coefficient for 0.25 inch air gap

= 0.0104 BTU/hr.ft.R Air thermal conductivity / 0.02 ft insulation gap

= 0.52 BTU/hr.ft^2.R

A = pipe total exposed surface area, from part number D010TVJAVCR-720

$$A = \pi(0.21ft) \times (65ft)$$

$$A = 43ft^2$$

$$G_i = \frac{73.4(1660-180)}{406 \times 96.5}\left(\frac{4.5-0.23}{4.5}\right)\sqrt{\frac{1 \times 180}{28}} = 6.7$$

$$Q_a = \frac{0.383(328-180)}{(922-180)} 1 \times 6.7 \times 0.52 \times 43ft^2 = 11cfm$$

Finding required capacity using CGA section 5.3.2, pressure relief device flow capacity under emergency conditions including fire.

$$Q_a = F \times G_u \times A^{.82}$$

Where,

Qa = flow capacity of the relief device

F= 1 , correction factor

Gu = 67, Cryogenic Liquid Nitrogen at (150 *1.21)= 181 psi, Gas factor from Table 1 for unisulated container.

A = area of a 10 foot length section of pipe exposed to fire
outer diameter of 2.5 inches. This is the diameter without vacuum jacket.

$A = \pi(2.5in) \times (120in)$, from part number D010TVJAVCR - 720

$A = 942in^2 = 6.6ft^2$

$$Q_A = (67.0) \times (6.6ft^2)^{.82} = 315 \frac{ft^3}{\min}$$

CONCLUSION

A trapped volume relief valve with a minimum capacity of 315 cfm is required.

Circle Seal K5120B-6M-150 valve meets these requirements

PRV-6202-LN
100 PSIG
Pressure Regulating Valve

The pressure regulating valve is used to set the operational condition of the vessel to 100 psig. In the event that the cryo-cooler fails or is unable to keep up with the heat load, the regulating valve opens to vent excess gas build up in the reservoir. The cryocooler capacity is 320 Watts at 80K

The pressure regulating valve is sized to vent gas generated by a 400 Watt system heat load.

Heat load = 400 J/s * 60s/min * 1 kJ/1000 J = 24 kJ/min
Latent Heat of vaporization = 161 kJ/kg

Amount of Nitrogen Vaporized = 24 kJ/min / 161 kJ/kg = 0.15 kg/ min

Density of Nitrogen at (100 psi/ 14.7 psi) 6.8 atmospheres = 3.484 kg/m^3 * 6.8 = 23.7 kg/m^3

Amount of Nitrogen Vaporized = 0.15 kg/ min / 23.7 kg/m^3 = 6.3e-3 m^3/min = 0.15 cfm

Conclusion:
A pressure regulating valve with a minimum capacity of 0.15 cfm is required to keep up with the heat load in the event that the cryo-cooler cannot.